Patent Application of

Pepi Dakov

for

Connectors for Hollow Anatomical Structures and Methods of Use

This is a continuation-in-part application of US patent application Ser. No. 09/479,792 from 01/08/2000, which is a continuation-in-part of US patent application Ser. No. 08/858,275 from 05/19/1997 now a US patent 6,030,392 from 02/29/2000.

FIELD OF THE INVENTION

This invention pertains to devices for joining hollow anatomical structures and more specifically to connectors for hollow anatomical structures.

BACKGROUND OF THE INVENTION

The most important and difficult part of the work of the surgeon is to perform anastomoses of hollow anatomical organs. At the end of the twentieth century, most of the surgical anastomoses are still performed in same way as hundred years ago -- by manual suturing.

Blood vessels are anastomosed by multiple manually placed stitches. The surgical procedure is time consuming and demands highly specialized skills. This is associated with a substantial rate of complications due to ischemia in the tissues suffering from the interrupted blood supply during the procedure. Bleeding frequently occurs from the suture lines. Remaining blood clots and persistent drains increase the chances for development of infections. Subjective technical mistakes by the surgeon can result in stenosis or thrombosis of the anastomosis.

Anastomoses of gastrointestinal organs have been automated to some extent by circular staplers. In brief, their method of operation is: first, an anvil and a stapling cartridge are introduced inside the ends of two hollow organs through a side slit of one of them; second, the ends of the two organs are inverted between the stapling cartridge and the anvil by two manual sutures; and third, multiple staples are ejected axially from the cartridge, they pierce the inverted walls of the two organs and are clinched by the anvil.

Circular staples have proven to perform more reliable anastomoses as compared to these accomplished by manual stitches. Still, their benefit is outweighed by several drawbacks. First, the time needed to complete the anastomosis is not actually reduced as the surgeon has to place two manual sutures to invert the ends of the two organs and after that has to suture manually the incisional slit. Second, the higher risk of technical failure associated with the process of manual suturing remains present as the surgeon has to close the incisional slit by multiple hand stitches. And third, the application of circular staples is limited only to relatively large organs, such as the intestines and the stomach.

Joining of hollow anatomical organs with artificial structures is also difficult as performed by the current surgical methods. That is particularly problematic for intestinal organs, for which there are no reliable methods for joining with artificial structures.

It is evident, that development of devices and methods for quick, easy, and reliable anastomoses of hollow anatomical organs is extremely important for reducing the

complications and improving the outcome in many surgical procedures, especially in cardiovascular surgery.

Various stapling devices have been proposed for implementation with blood vessels. Most of them are based on a similar method of operation as that of circular staplers -- to suture the ends of blood vessels by axially ejected staples. The walls of blood vessels cannot be inverted (as the walls of gastrointestinal organs) because this will impede the blood flow. For that reason, blood vessels are either everted or cuffed before being stapled by the proposed stapling devices. Everting or cuffing body organs is more difficult and time consuming to perform than inverting. This is particularly true for blood vessels, which in general are located in less accessible places and have more rigid walls than intestines. Sometimes, this is even impossible to perform sometimes when the vessels are with substantially rigid walls (such as arteries with atherosclerotic changes). For these reasons, none of these stapling devices for blood vessels has established a practical application.

A device for accomplishing anastomoses of blood vessels, without changing their natural configurations, by ejecting staples in radial direction, is described by Perouse (U.S. - 5,346,115). The described device has several important limitations. It can be used only for attachment of a non-rigid graft to the internal surface of a blood vessel. The internally attached graft narrows the lumen of the vessel. This limits the application of the device only to relatively large vessels. Direct anastomosis (without a graft) of two blood vessels cannot be accomplished. The device can be used only for end-to-end anastomosis. Side-to-end anastomosis cannot be performed.

A side-to-end vascular staple apparatus and method of stapling is described by Kaster et al. in US Pat. No. 5,234,447, in US Pat. No. 5,366,452, and in US Pat. No. 5,403,333. In the described method, one of the vessels is inserted through a mandrel and cuffed over the end of the mandrel. The procedure can be performed only if the other end of the vessel is loose, as the mandrel has to be withdrawn back after the completion of the procedure. Therefore, the staple apparatus can be used to

anastomose only the first end of a vessel graft. It cannot be used to anastomose the second end of the graft because the mandrel cannot be withdrawn after the first end is joined. This is a major practical limitation of the described apparatus and method. Furthermore, the diameter of the staple apparatus, after the interior engagement members are bent, is larger than the diameter of the side opening. This makes difficult the insertion of the staple apparatus into the vessel. Deforming the internal engagement members consequently one by one slows additionally the anastomosing procedure. And finally, the end-anastomosed vessel needs to be cuffed in order to perform the procedure. As explained above, this is an important limitation for the practical application of the described apparatus and method.

Many authors have proposed various types of rigid connectors for performing quick anastomoses of hollow organs. While the connectors differ much in structures and forms, their method of operation is principally the same. Two hollow body organs become joined by compressing their flanged (everted or inverted) or cuffed walls between the rigid surfaces of two coupled connectors.

Compressing body organs between rigid connectors is associated with a very high risk of serious complication. Applying a constant pressure on a substantially large area of body tissues produces adverse changes in the tissues. The compressed tissues suffer ischemic changes due to the decreased blood-oxygen supply. A high pressure deprives the tissues from blood-oxygen supply. This results in a necrosis, which may lead to rupture of the anastomosed organs. A moderate pressure diminishes the blood-oxygen supply. This slows the metabolism and the regeneration of the tissues. The compressed tissues become thinner while their healing is impeded. This may lead to a leak of the anastomosis before the tissues are healed. On the other hand, applying a light pressure may be inadequate to join the organs in a fluid tight manner, which can manifest with an immediate leak of the anastomosis.

Because of the significant risk of serious complications, none of these rigid connectors has found practical utilization. In addition, the walls of at least one of the two

anastomosed organs must be flanged or cuffed. As it was explained above, this alone is a major limitation for the practical application of the connectors.

The present invention solves all these problems. It provides a new connector and methods for attaching the connector to hollow anatomical organs in an easy, fast, and reliable manner, which is overall superior to the currently used devices and methods for anastomosing and to these known of the prior art. The new connector has a wide and universal application. It can be used to perform end-to-end or side-to-end anastomoses of different hollow structures. It can be used for anastomoses of hollow body organs, for bypass and shunt procedures, for implantation of hollow artificial devices, for organ transplants, for intestinal stomas, and for other surgical procedures.

OBJECTS AND SUMMARY

It is a primary object of this invention to provide connectors for anastomosing a hollow anatomical structure with another hollow structure.

It is another object to provide a method for anastomosing a hollow anatomical structure with another hollow structure by connectors.

It is a further object to provide connectors that are simple to manufacture, easy to use, and cost-effective to implement.

These objects, and others are achieved in a connector comprising an annular rigid body and multiple holding members. The inner surface of the annular body conforms to the external surface around a wall-opening of a hollow anatomical structure. Holding means are affixed to the annular body. They holding means press the anatomical organ towards the annular body on the outside and keep the organ adjoined to the inner fluidproof surface of the rigid body. Embodiments for attachment to end-openings or to side-openings of anatomical organs are provided. The union of the annular body with another annular body of another connector attached to another hollow structure forms a

fluidproof surface that surrounds the abutted cut-edges of the two approximated hollow structures.

Various modifications in the form and the structure of the connectors in accordance with the specific tissue and organ requirements are described. An additional instrumentation that facilitates the surgical implementation of the connectors is further provided. The implementation of the connector for new types of surgical procedures is shown.

A better understanding of the present invention along with its many attendant objects and advantages, may be obtained from consideration of the following description of the preferred specific embodiments, particularly when read in conjunction with the appended drawings, a brief description of which follows:

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A**, **1B** and **1C** illustrate an end connector positioned above a hollow tubular organ. They are shown in a perspective view in FIG. **1A**. The same connector and organ crosscut in half are shown in a perspective view in FIG. **1B**. A portion of them (encircled by window **C*** in FIG. **1B**) is shown magnified in a schematic front view in FIG. **1C**.

FIGS. **2A**, **2B**, and **2C** illustrate the connector positioned over the end of the hollow organ and a pusher above them. They are illustrated in the same views as in FIGS. **1A**, **1B**, and **1C** respectively.

FIGS. **3A**, **3B** and **3C** illustrate the holding members being deformed by the pusher inserted into the hollow organ. They are illustrated again in the same views as in the previous figures.

FIGS. **4A**, **4B** and **4C** illustrate the connector attached to the end-opening of the hollow organ. They are illustrated again in the same views as in the previous figures.

FIGS. **5**, **6**, and **7A** illustrate in perspective views accomplishing an end-to-end anastomosis of two hollow tubular organs by a union of the connectors attached to their ends. The connectors are further provided with coupling arms.

FIG. **7B** illustrates in a perspective view the end-to-end anastomosis accomplished by a union of the end connectors, showing the anastomosis crosscut in half.

FIGS. **8A** and **8B** illustrate an end connector and a side connector positioned adjacent to the end and side-openings of two hollow tubular organs. The elements are shown in a side-front-top perspective view in FIG. **8A** and crosscut in half in a side-front-bottom perspective view in FIG. **8B**.

FIGS. **9A** and **9B** illustrate the two connectors positioned over the two hollow organs and a pusher directed perpendicularly to the side connector. They are shown in the same views as in FIG. **8A** and **8B**.

FIGS. **10A** and **10B** illustrate the pusher deforming the holding members of the side connector, showing them in the same views as in the previous figures.

FIGS. **11A** and **11B** illustrate the end connector and the side connector attached to the two hollow tubular organs, showing them in the same views as in the previous figures.

FIGS. **12**, **13**, and **14A** illustrate performing a side-to-end anastomosis of two hollow tubular organs by a union of the connectors attached to them, showing them in side-front-top views. The connectors are further provided with coupling arms.

FIG. **14B** illustrates in a perspective view the side-to-end anastomosis accomplished by a union of the attached connectors, showing the anastomosis crosscut in half.

FIGS. **15**, **16**, **17** illustrate in perspective views three different embodiments of end connectors with different holding members, showing the embodiments crosscut in half.

FIGS. **18A** and **18B** illustrate in perspective views a different embodiment of an end connector with an annular body comprising a wire mesh.

FIGS. **19A** and **19B** illustrate in perspective views a different embodiment of an end connector comprising an annular body lined internally with a layer of fabric.

FIGS. **20A**, **20B** and **20C** illustrate in perspective views a different embodiment of an end connector with an annular body comprising multiple arcuate segments bound by a bioabsorbable strip.

FIGS. **21A** and **21B** illustrate in perspective views a side-to-end anastomosis of two hollow organs accomplished by a union of connectors with different coupling configurations of their annular bodies.

FIGS. **22A** and **22B** illustrate in perspective views a side-to-end anastomosis at acute angle of two hollow organs accomplished by a union of connectors with different means for coupling.

FIGS. **23A** and **23B** illustrate in schematic front views other means for deforming the holding members of a side connector.

FIG. **24** illustrates in a perspective view other means for deforming the holding members of an end connector.

FIG. **25** illustrates in a schematic front view other means for checking and deforming the holding members of a side connector.

FIGS. **26A** and **26B** illustrate in perspective views a connector-holder used to hold and align an end connector with a pusher.

FIGS. **27A** and **27B** illustrate in perspective views an organ-holder used to hold and align the end of a hollow tubular organ.

FIG. **28** illustrates in a perspective view the connector holder and the organ holder combined in a single front unit.

FIG. **29** illustrates in a perspective view a connector-applying instrument comprising a gun shaped body and a front unit.

FIGS. **30** through **33** illustrate in perspective views a cutting instrument for performing a side-opening in a hollow organ.

FIGS. **34** through **36** illustrate in perspective views a new method for constructing an intestinal stoma by a modified embodiment of an end connector.

FIGS. **37A**, **37B**, and **37C** illustrate an indivisible union connector positioned above a hollow anatomical structure. They are shown in a perspective view in FIG. **37A**. The same connector and hollow structure crosscut in half are shown in a perspective view in FIG. **37B**. A portion of them (encircled by window **C*** in FIG. **37B**) is shown magnified in a schematic front view in FIG. **37C**.

FIGS. **38A**, **38B**, and **38C** illustrate the union connector positioned over the end of the hollow structure. They are illustrated in the same views as in FIGS. **1A**, **1B**, and **1C** respectively.

FIGS. **39A**, **39B**, and **39C** illustrate the union connector attached to the end-opening of the hollow structure. They are illustrated again in the same views as in the previous figures.

FIGS. **40A**, **40B**, and **40C** illustrate end-to-end anastomosis accomplished with the union connector attached the ends of two hollow structure in the same view as in the previous figures.

FIGS. **41A** and **41B** illustrate a different embodiment of end connectors shown in perspective view in FIG. **41A**, the same elements crosscut in half in the same perspective view in FIG. **41B**.

FIGS. **42A** and **42B** illustrate and end-to-end anastomosis performed by the union of above connectors, showing it crosscut in half in perspective view in FIG. **42A**, and whole in the same perspective view in FIG. **42B**.

FIGS. **43A**, **43B**, and **43C** illustrate an indivisible union connector for side-to-end anastomosis in perspective top, perspective bottom, and crosscut perspective bottom views respectively.

FIGS. **44A** and **44B** illustrate the union side-to-end connector attached to the end of a hollow structure in perspective top and perspective bottom views respectively.

FIGS. **45A** and **45B** illustrate the union side-to-end connector of attached to the end of a hollow structure and positioned over the side-opening of another hollow structure in a perspective top and perspective bottom views respectively

FIGS. **46A** and **46B** illustrate a side-to-end anastomosis of two hollow structures by the union side-to-end connector shown in perspective bottom and in a perspective bottom crosscut view respectively.

FIGS. **47A** and **47B** are schematic illustrations of a different embodiment of a side-to-end union connector showing it with open and deformed holding members.

FIG. **48** is a schematic illustration showing the union side-to-end connector attached to the end of the first hollow structure.

FIG. **49** is a schematic illustration showing a side-to-end anastomosis performed by the union side-to-end connector.

Figs. **50A** and **50B** illustrate an embodiment of a union connector for end-to-end anastomosis of intestinal organs, showing it in a crosscut perspective view and a magnified schematic view respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the present invention, I have developed a connector for attachment to hollow anatomical structures in a sufficiently fast, easy and reliable manner.

A specific preferred embodiment of an end connector and a method for attaching the connector to an end of a hollow tubular organ are shown in FIGS. **1A** through **4C**. For better visualization and understanding, the elements are shown in different views. They

are shown in perspective views in FIGS. **A**. The same elements crosscut in half are shown in the same perspective views in FIGS. **B**. Portions of them, as defined by windows **C*** in FIGS. **B**, are shown magnified in schematic views in FIGS. **C**. Performing an end-to-end anastomosis of two hollow tubular organs attached with end connectors is shown in perspective views in FIGS. **5** through **7A**. The end-to-end anastomosis crosscut in half is shown in a perspective view in FIG. **7B**.

An end connector **40** is shown above an end-opening **66** of a hollow tubular organ **64** in FIGS. **1A, 1B** and **1C**. The connector **40** has an annular rigid body **42** and multiple holding members **46**. The annular body is made of a material that is substantially rigid to sustain a stable coupling shape, such as a metal, a metal alloy, a hard plastic, or any other material with alike properties. The inner surface of the annular body has a predefined form that conforms to the external surface of the anatomical organ. In this case, the connector has an inner cylindrical surface that corresponds to the external cylindrical surface of the hollow organ. The opening **44** of the annular body **42** approximates the opening **66** of the hollow organ **64**. The holding members **46** are made of a substantially rigid material that by an applied force can be deformed from one memory resident form to another memory resident form. Such a material can be made of various types of metal or metal alloy, such as stainless steel, or any other substance with like properties. The holding members **46** have a "U" shaped staple-like form consisting of first and second pointed ends **48** and **50** that are interconnected with a crossbar **52**. With the first pointed ends **48**, the holding members are affixed to the annular body **42** spaced apart along its opening **44**.

Attaching the connector to the end of the hollow organ is illustrated in FIGS. **2A** through **4C**. The connector **40** is positioned over the opening **66** of the hollow organ **64,** as shown in FIGS. **2A** through **2C**. A pusher **54** is shown positioned above them. The pusher acts to deform the holding members. The pusher is made of a substantially hard material such as a metal, a metal alloy or of any other substance with alike properties. It has an approximately cylindrical body **56** affixed to the front end **62** of a rigid rod **60**. The

cylindrical body **56** has a dome-like front end **58**. The external diameter of the cylindrical body of the pusher approximates the internal diameter of the hollow organ.

Permanent attachment of the connector to the hollow organ is accomplished by deforming the holding members. This is illustrated in FIGS. **3A** through **3C**. By an applied force, the pusher **54** is moved axially downward into the opening **44** of the connector **40**. The front end **58** of the pusher **54** exerts gradually increasing pressure on the holding members **46.** This pushes and deforms the holding members in axial direction downward and in radial direction outward them. The holding members **46** bend along the points of attachment to the annular body **42.** The deformed holding members **46** protrude into the opening **66** of the hollow organ **64**. The crossbars **52** of the deformed holding members **press** from inside the wall of the hollow organ **64** towards the outside annular rigid body **42** of the connector **40**. The second pointed ends **50** of the deformed holding members **46** pierce perpendicularly the wall of the hollow organ **64**, which anchors the connector to the wall of the hollow organ. In this way, the connector becomes steadily attached to the opening of the hollow organ.

Performing an end-to-end anastomosis of two hollow tubular organs **64** and **68** attached with end connectors **40** is shown in a specific embodiment in FIGS. **5** through **7A**. The end connectors comprise the same elements as described above -- annular rigid bodies **42** and multiple holding members **46**. The connectors are further equipped with means for coupling them. Multiple coupling arms **70** are attached with their first ends **72** to the outer surfaces of the annular bodies **42**. The second ends **74** of the arms **70** have a predefined bud-like shape. The two organs **64** and **68** attached with connectors **40** and are shown close to each other in FIG. **5**. To join the organs, the connectors **40** are first brought together, as shown in FIG. **6**. After that the connectors **40** are rotated in opposite direction until the second ends **74** of their coupling arms **70** interlock into a permanent and stable position, as shown in FIG. **7A**.

The union of two coupled connectors forms a fluidproof surface that surrounds the ends of the two organs being approximated and abutted with the cut-edges of their wall-openings. This precludes any possibility for a leak between their abutted edges. In this way, the two hollow organs attached with end connectors are anastomosed quickly, easily and reliably.

The end-to-end anastomosis of two hollow organs accomplished by connectors is seen best in FIG. **7B.** This is an inside perspective view of the anastomosis, which is shown crosscut in half. As seen, the two organs **64** and **68** are exactly approximated with a minimal gap **76** between them. The size of the gap corresponds to the thickness of the holding members **46**.

The circular staplers used currently for performing anastomoses of large gastrointestinal organs operate with staples made of wire with a diameter of approximately 0.01 mm. Wire with the same diameter can be used to produce the holding members of connectors for gastrointestinal organs. Then the gap, formed between the two gastrointestinal organs anastomosed by connectors, will also be 0.01 mm. Therefore, the gap is very narrow even for relatively large body organs. Accordingly, the gap is smaller for smaller body organs.

The narrow gap is quickly filled by the opposing edges of the two organs. Cutting body organs constitutes a trauma to their walls. The traumatized tissues are infiltrated quickly within the first hours and remain swollen for the next 36-48 hours. In this period, the swollen cut-edges of the two organs protrude between the holding members. The infiltrated tissues fill the small gap and the cut-edges contact with each other which actually eliminates the gap.

As seen, the two organs are exactly approximated and abutted with the cut-edges of their wall-openings. The internal, the medial, and the external layers of each of the two organs oppose and meet precisely with the same layers of the other organ. This leads to a fast and reliable healing that is a layer specific. A layer specific healing means that the internal, the medial, and the external layers of the two organs heal and join with each

other. Such type of healing cannot be achieved with the current anastomotic devices. In majority of the current methods, the walls of the anastomosed organs are either inverted (gastrointestinal organs) or everted (blood vessels) and organs become joined by heeling of their external or internal layers only. Some current devices join organs by overlapping their walls. This positions in healing contact different layers, which leads to slow and weak healing.

A side connector for attachment to a side-opening of a hollow tubular organ and a method for performing a side-to-end anastomosis are described next in a specific preferred embodiment. Attachment of a side connector **78** to a first hollow tubular organ **100** and an end connector **90** to a second hollow tubular organ **104** is shown in FIGS. **8A** through **11B**. The elements are shown whole in perspective views in FIGS. "**A**". The same elements are shown crosscut in half in perspective views from a lower point of view in FIGS. "**B**". Accomplishing a side-to-end anastomosis of the two organs by the union of connectors attached to them is shown in Figs. **12** through **14B**.

The side connector **78** is based on the same principle as described above with the end connector. It has an annular rigid body **80** and multiple holding members **84**. The annular body is made of a material that is substantially rigid to sustain a stable coupling form, such as a metal, a metal alloy, a hard plastic, or any other material with alike properties. The inner surface of the annular body has a predefined form that conforms to the external surface of the anatomical organ. In this case, the inner surface of the annular body corresponds reciprocally to the external surface of the sidewall of the first hollow organ. The opening **82** of the annular body **80** corresponds to the side-opening **102** of the first hollow organ **100**.

The holding members **84** of the side connector **78** also follow the principles described above with the end-connector. They are made of a substantially rigid material that by an applied force can be deformed from one memory resident form to another memory resident form. The holding members have a "L" shaped form. They consist of

shorter first arms **86** and longer second arms **88**. With their first arms **86**, the holding members **84** are affixed to the annular body **80** spaced apart along its opening **82**.

The end-connector **90** of this embodiment also has an annular rigid body **92** and multiple holding members **96**. The form of the annular body **92** and its opening **94** correspond respectively to the form of the second hollow organ **104** and its end-opening **106**. The end-opening **106** of the second hollow organ **100** matches the side-opening **102** of the first hollow organ **100**. The multiple holding members **96** of the end connector **90** resemble the "U" shaped holding members of the end connector described above for end-to-end anastomosis. They are with staple-like configuration, they are positioned spaced apart along the opening of the connector and directed towards the lumen of the hollow organ. In addition, the holding members **96** have short arms **98** by which they are attached to the annular body **92** of the connector **90**, as seen in the crosscut views in FIGS. **8B** and **9B**. These short arms extend the holding members **96** axially and downward. This extension equals to the thickness of the annular body **80** of the side connector **78**. In this way, when the two connectors **78** and **90** are coupled, the end of the second hollow organ **104** protrudes downward and contacts the wall of the first hollow organ **100**.

Deforming the holding members **84** of the side connector is accomplished by a pusher **108**, which is shown in FIGS. **9A** through **10B**. It is performed in the same manner as described above with end-to-end connectors. The pusher **108** is moved down into to the opening **82** of the side connector **78**. The dome front end **110** of the pusher **108** exerts gradually increasing pressure axially downward and radially outward on the holding members **84**. The holding members **84** bend along the point of attachment to the annular body **80** into the side-opening **102** of the first hollow organ **100**. The second arms **88** of the deformed holding members **84** press the wall of the first hollow organ **100** from the inside towards the annular rigid body **80** on the outside. In this way, the side connector is attached steadily to the sidewall of the first hollow organ. The holding members **96** of the end connector **90** are deformed in the same way as depicted above

with end-to-end connectors, so this is not described again. The two connectors **78** and **90** attached to the two hollow organs **100** and **104** are shown in FIGS. **11A** and **11B**.

A side-to-end anastomosis of the two organs **100** and **104** is performed by coupling the two connectors **78** and **90** attached to them in a fluidproof union, which is shown in a specific preferred embodiment in FIGS. **12** through **14B**. The connectors are further equipped with means for coupling them. Multiple locking arms **112** are affixed with their first ends **114** to the outer surface of the annular rigid body **80** of the side connector **78**. They are positioned perpendicular and spaced apart so they can accept the annular body **92** of the end connector **90**. The second ends **116** of the locking arms **112** are curved inwardly in a hook-like form.

Anastomosis of the two organs **100** and **104** is accomplished by bringing together the connectors **78** and **90** attached to them. The locking arms **112** of the side connector **78** encompass and lock by their second ends **116** the annular body **92** of the end connector **90**. The union of the two coupled connectors forms a fluidproof surface that surrounds the cut-edges of the two approximated organs, which securely precludes leaks out of the anastomosis. In this way, the two organs are anastomosed easily and reliably.

The side-to-end anastomosis of the two organs is seen best in inside view in FIG. **14B**. As seen, the two organs **100** and **104** are precisely approximated and abutted with cut-edges of their openings, which are closely adjacent to each other with a minimal gap **118** between them. The union of the two annular bodies forms a fluidproof surface that surrounds the cut-edges of the two organs and prevents leaks out of the anastomosis. This warrants fast and reliable healing of the two organs.

The connector of the present invention can be used for variety of purposes with different body organs and artificial structures. They can be used with arteries, veins, small or large bowels, stomach, bile duct, ureter, and other hollow body organs such as the skull, thorax or abdomen. They can be also used with artificial grafts or organs, such as vessel grafts or total artificial hearts, for replacing the natural body structures and

organs. All these organs and structures differ physiologically, anatomically, and functionally. Their walls may be rather thick (stomach), or thin (veins). The pressure inside them may be very high (arteries), or low (intestines). They may conduct different types of fluids that are erosive (urine), or not erosive (blood). They may contain secreting glands in their walls (gastrointestinal organs), or have no glands (blood vessels). Their regenerative and healing capacities may be fast (intestines), or slow (ureters).

Without departing from the principles of the present invention described above, various modifications in the form and the structure of the connectors can be made easily in order to comply with the specific needs of the different anatomical structures. Several such modifications are shown next.

Three specific embodiments of end connectors with modified holding members are shown crosscut in half in perspective views in FIG. **15**, FIG. **16** and FIG. **17**. In the first embodiment of FIG. **15**, the holding members are a combination of "U" shaped members **226** and "L" shaped members **228** affixed to the annular rigid body **214**. The "L" shaped members are shorter than the "U" shaped members. The connector **202** is anchored to the hollow organ **200** by the pointed ends of the "U" shaped holding members **226**. The "L" shaped holding members **228** only press the wall of the organ near the end. In this way, the wall of the hollow organ remains well pressed to the annular body of the connector, while it is punctured only by half of the holding members. This decreases the risk of rupture of the hollow organ in the puncture line. Such embodiment can find useful application for organs that have fragile walls and do not conduct fluid under high pressure (e.g., veins and intestines).

Two other embodiments of connectors **204** and **206** with different type of holding members are shown in FIGS. **16** and **17**. The holding members **230** have a cross shape in the first embodiment **204** in FIG. **16**, and an arrow shape **232** in the second embodiment **206** of FIG. **17**. In both cases, the number of the holding members is reduced and each of the members presses the hollow organ **200** on a larger surface.

Such embodiments may find application for organs with thick walls and/or slow regenerative capacities (e.g., stomach or ureters).

The annular rigid body of the connector can also be modified, as illustrated next. A specific embodiment of an end connector **208** is shown adjacent and attached to the end of a hollow body organ **200** in FIGS. **18A** and **18B** respectively. In this case, the connector consists of a narrow rigid ring **216** and a wire mesh ring **218** below it. This embodiment has two distinctive features. First, the mass and accordingly the weight of the connector are reduced. Second, a connective tissue from the external layer of the body organ can grow into the wire ring and produce a natural attachment of the connector to the body organ.

Another specific embodiment of an external end connector **210** with a modified annular body is shown in FIGS. **19A** and **19B**. The rigid annular body **214** is lined on the inside with a thin layer of fabric **220** that is woven, knitted or braided. Such layer of fabric can be made of Dacron™, Teflon™, or others brands, which have already been proven biocompatible for vessel prostheses.

As the fabric **220** remains entirely outside the lumen of the hollow body organ **200**, fabrics made of less biocompatible fibers can be used as well. In addition, the inner surface of the annular body of the connector can also be covered with any other substance that has a porous microstructure that allows the ingrowth of connective body tissue.

The connector lined internally with fabric material has two important features. First, the fabric material cushions the connector so the body organ is not pressed to a hard surface. Second, connective tissue fibers can grow from the external surface of the body organ into the porous structure of the fabric material. This produces natural healing and attachment of the connector to the body organ.

Another specific embodiment of an end connector with a modified annular rigid body is shown in perspective views FIGS. **20A**, **20B**, and **20C**. The connector **212** is shown

above the end of hollow body organ **200** in FIG. **20A** and attached to it in FIG. **20B**. The annular rigid body of the connector **212** is formed by multiple arcuate rigid segments **222** that are kept in a stable annular formation by an annular stripe **224**. The annular stripe **224** is made of a bioabsorbable material that is absorbed by the body within two weeks to six months. During this period the anastomosed body organs have joined reliably by natural healing. Later, when the body organ **200** grows and enlarges, the arcuate segments **222** distance from each other, as shown in FIG. **20C**. In this way, the connector does not restrict the physiological growth of the body organ. Such an embodiment can find particularly beneficial application in pediatric surgery.

A further simplification and improvement of this embodiment is to manufacture the entire annular body of the connector only of bioabsorbable material, when such a suitable material that is rigid enough to sustain a stable coupling shape proves to be available in practice. It is preferable to manufacture also the holding members from absorbable material, when such a material that is rigid and can be deformed from one memory resident form to another form becomes available.

The connectors can be produced with various configurations for coupling. A side-to-end anastomosis of two organs **234** and **236** accomplished by specific embodiments of connectors **238** and **242** that plug into each other is shown in FIGS. **21A** and **21B**. In this case, the side connector **242** further comprises a cylindrical portion **246** affixed perpendicularly to the annular rigid body **244**. The cylindrical portion **246** has predefined form and dimension to accept and encompass tightly the annular rigid body **240** of the end connector **238**. The connectors are joined in stable position by multiple hook-like coupling arms **248** of the side connector **242**, which lock around the annular body **240** of the end connector **238**.

Another specific embodiment of connectors for accomplishing side-to-end anastomosis of two hollow tubular organs **250** and **252** is shown in FIGS. **22A** and **22B**. The end connector **254** is coupled to the side connector **260** at an acute angle. In this case, the illustrated connectors are coupled at angle of 60 degrees. The side-opening is

not strictly cylindrical, but oval. In this way, the anastomosis is performed on a relatively flat surface. The two connectors **254** and **260** are coupled and locked in a stable position by a den **258** of the end connector that fits in a recess **264** of the side connector **260**, and by an arm **266** of the side connector **260** which by two branches **268** braces the annular body **256** of the end connector **254**.

The holding members can be deformed by a variety of means and methods, some of which are described next. Other means for deforming the holding members **274** of a side connector **272** are shown schematically in FIGS. **23A** and **23B**. Multiple levers **276** are hinged with their first ends **278** to a rigid ring **282**. With their second ends **280**, the levers **276** abut the holding members **274**. A pusher **284**, with an approximately cylindrical body and a dome like front end, is positioned in a central axial orientation. By an applied force, the pusher **284** is moved axially down. This pushes the levers **276** radially and outwards. The levers **276** turn along their first ends **278**. The second ends **280** of the levers **276** move in a radial direction outward, which deforms the holding members **274**, which is illustrated in FIG. **23B**.

Other means for deforming the holding members **296** of an end connector **294** are shown in FIG. **24**. In this embodiment, the pusher **286** consists of multiple rigid plates **288** arrayed radially over a cylinder **290**. The plates **288** are inwardly curved so the front end of the pusher has overall a dome-like shape. When the pusher **286** is moved downward, the plates **288** exert pressure only on the holding members. In this way, the hollow organ **294** is not traumatized by the pusher **286**.

The holding members can be deformed also by very simple means. This is illustrated schematically in FIG. **25**, which shows deforming the holding members of a side connector **272** attached to a hollow organ **270**. The holding members are deformed one by one with an appropriately curved spatula **298**, which is rotated and pulled up consecutively. This method can be used exclusively or in addition to the other shown

and known methods. With the spatula, the surgeon can check the position of the holding members deformed by another method and to bend them additionally, if needed.

The methods described above are just exemplary illustrations for deforming holding members by externally applied forces and other known methods can be implemented for this purpose.

It should be noted that intrinsic elastic forces can also be used to deform the holding members. The holding members can be made by a highly elastic rigid material such as nickel and titanium alloy (nitinol) metal. In such cases the holding members are initially modeled in the desired deformed shape. Then, they are opened so they can accept the wall of the hollow organ. When released, they return back to their initial shape under their intrinsic elastic force.

The surgical procedure for attaching a connector to a hollow organ can be further automated and facilitated by additional instrumentation. An exemplary illustration of such instrumentation is a specific embodiment of a connector-applying mechanism shown next. For better visualization and understanding, the components of this mechanism are shown and described consecutively. First, an instrument that holds the connector, referred to as a connector holder **300**, is shown in FIGS. **26A** and **26B**. After that, an instrument that holds the end of a hollow organ, referred to as an organ holder **338**, is shown in FIGS. **27A** and **27B**. The connector holder and the organ holder combined in a single front unit **364**, are shown in FIG. **28**. The whole connector-applying mechanism **362** is illustrated in FIG. **29**.

The connector holder **300**, illustrated in FIGS. **26A** and **26B**, consists of a pair of pivoted jaws **302** attached to a central cylinder **312**. The jaws **302** consist of semi circular arcuate portions **304** positioned at the lower ends **308** and of two long arms **306** extending upward. The arcuate portions **304** encompass tightly the annular body **330** of the connector **328** when the jaws are closed. The arms **306** are pivoted to two radial projections **313** of the central cylinder **312** at points closer to the upper ends **310** of the

arms. A first sliding cylinder **316** that has a small radial flange **318** is slidingly positioned over the central cylinder **312**. Two beveled levers **320** are joined pivotally with their ends to the upper ends **310** of the arms **306** and to the radial flange **318** of the first sliding cylinder **316**. A pusher **320**, consisting of multiple radial plates **324** is used to deform the holding members **332**. The rigid rod **326** of the pusher **320** extends axially upward through a bore **314** of the central cylinder **312**.

When the first sliding cylinder **316** is moved down, the beveled levers **320** push the upper ends **310** of the arms **306** radially and outward. The arms **306** turn around their pivoting points with the radial projections **313** of the central cylinder **312**. Their lower ends **308** move in inward radial direction. The arcuate portions **304** of the jaws **302** brace the annular body **330** of the connector **328** and hold it in a stable position. In this way, the connector **328** is oriented precisely with the axis of the pusher **322**. Moving up the first sliding cylinder **316** opens the jaws and releases the connector **328** after the procedure is completed.

The organ holder **338** is illustrated in perspective views in FIGS. **27A** and **27B**. It keeps the end of a hollow organ **334** in a stable position during the attachment procedure. Multiple long wire pins **340** are used to hold the hollow organ **334**. The wire pins **340** extend axially and are curved radially inwards. The lower ends **342** of the pins **340** are angled perpendicularly to the wall of the hollow organ **334**. The upper ends **344** of the wire pins **340** are attached to a rigid ring **346**. The ring **346** is attached by four "L" shaped supporting arms **348** to a basic cylinder **350**. A second sliding cylinder **352** is slidingly positioned over the basic cylinder **350**. The second cylinder **352** has an outward radial flange **354** in the lower end.

During the procedure, the basic cylinder **350** is moved down so the lower ends **342** of the pins **340** are positioned just below the edge of the hollow organ **334**, which is illustrated in FIG. **27A**. Then, the second sliding cylinder **352** is moved down, as shown in FIG. **27B**. Its flange **352** pushes the wire pins **340** in an outward radial direction. The

lower ends **342** of the pins **340** move outward radially. They pierce the wall of the hollow organ **334** and expand it to an exact cylindrical configuration. In this way, the hollow organ is held in a stable position mounted on the wire pins.

The connector holder **300** and the organ holder **338** are combined in a single front unit **364**, which is shown in FIG. **28**. The basic cylinder **350** of the organ holder **338** is slidingly positioned over the central cylinder **312** of the connector holder **300**. In this way, the hollow organ **334**, the connector **328**, and the pusher **322** are all held in a stable position and aligned precisely with each other. Three pairs of axially extending bars **356**, **358**, and **360** are affixed accordingly to the first sliding cylinder **316**, to the basic cylinder **350**, and to the second sliding cylinder **352**.

The connector-applying mechanism **362** is shown in FIG. **29**. It consists of a gun shaped body **366** and the single front unit **364**. The drawing illustrates in general the major components of the body of the connector-applying mechanism. It consists of a handle **368**, a trigger **370**, and an elongated tubular portion **372**. The elongated portion **372** consists of axial extensions of the same components as of the front unit: an extension **374** of the central cylinder **312**; an extension **376** of the rigid rod **326** of the pusher **322**; and three pairs of extension **378**, **380**, and **382** of the three pairs of bars **356**, **358**, and **360** of the first sliding cylinder **316**, the basic cylinder **350**, and the second sliding cylinder **352** respectively. Two thin circular plates **384**, affixed perpendicularly to the extension **374** of the central cylinder **312**, sustain and direct the movement of the three pairs of extensions **378**, **380**, and **382** in an axial direction.

Each of the three pairs of extensions continues through the handle and ends with a button situated on the backside of the handle. The first button **386** is the end of the extension **378** of the pair of bars **356** affixed to the first sliding cylinder **316**, which is coupled to the upper ends of the jaws **302**. Pushing down the first button **386** moves down the first sliding cylinder **316**, which closes the jaws **302** of the connector holder **300**. The second button **388** is the end of the extension **380** of the pair of bars **358** of the

basic cylinder **350**, to which the multiple wire pins **340** are attached. Pushing down the second button **388** introduces the lower ends **342** of the wire pins **340** into the hollow organ **334**. The third button **390** is an extension **382** of the pair of bars **360** affixed to the second sliding cylinder **352**. Pushing down the third button **390** moves down the second sliding cylinder **352**, which expands the wire pins **340** that keep the organ in a stable position.

The trigger **370** is coupled to the extension 376 of the rigid rod **326** of the pusher **322** by a trigger mechanism in a manner that pulling the trigger moves axially downward the extension of rigid rod. In this way, pulling the trigger **370** moves down the pusher **322**, which deforms the holding members **322** of the connector **328**. The trigger mechanism can be executed in many already known from prior art methods, one of which was shown in the parent patent application, and this is not described here in details.

The surgeon attaches the end connector **328** to the opening **336** of the hollow organ **334** by the connector-applying mechanism **362** in an quick and easy way. First, the connector-applying mechanism **362** is assembled. The surgeon selects a connector **328** and a front unit **364** with appropriate sizes that correspond to the dimensions of the hollow organ **334**. Then, the surgeon couples the front unit **364** to elongated portion **372** of the gun shaped body **366**. By pushing the first button **386** down, the jaws **302** of the connector holder **300** grasp the connector **328** in stable position. It should be noted that front units with different sizes (and accordingly connectors) can be coupled to a same gun shaped body. This improves the cost effectiveness of the connector-applying mechanism.

After the connector-applying mechanism **362** is assembled, the surgeon begins the actual attachment of the connector **328** to the hollow organ **334**. First, the second button is pushed down which introduces the pins **340** into the hollow organ **334**. Then, the surgeon pushes down the third button **390**, which expands the pins **340** and secures the organ **334** in a stable position. After that the surgeon pulls up the second button **388**,

which aligns the end of the mounted organ **334** with the connector **328**. At this moment, the trigger **370** is pushed. This moves down the pusher **322** and deforms the holding members **332**. In this way, the connector **328** becomes attached to the hollow organ **334**. After that, by pulling up the third **390** and the first button **286**, which respectively collapse the wire pins **340** and open the jaws **302**, the connector-applying mechanism **362** is released and removed away.

Using the connector-applying mechanism, the surgeon can attach the connector from a distance only with one hand. This allows the connector to be attached in minimally invasive procedures under endoscopic control. For application with relatively large body organs (such as intestines), the connector-applying mechanism can be modified further. An endoscopic apparatus can be introduced through a bore of the rigid rod of the pusher. This will provide the surgeon with a good central view of the organ and the connector during the procedure.

The connector-applying mechanism was described above in general. Minor details that are obvious to one skilled in the art were not shown. For example, by matching ridges and grooves, the pusher and the connector can by aligned so the radial plates of the pusher are aligned with the holding members of the connector. In the same way, the basic, first and second sliding cylinders can be directed to move strictly axially without any rotation. Also, springs and other means can be used to keep the moving elements in a basic position.

The connector-applying mechanism shown above should be considered a basic exemplary illustration of such a mechanism. Many modifications in its structure can be made by one skilled in the art. In a similar manner, a connector-applying mechanism for attaching a side connector can be constructed.

An exact matching of the openings of the connector and the hollow organ is needed in order to attach the connector easily and reliably. A side-opening of a hollow tubular organ is rather difficult to perform as the side-opening has a rather complex configuration that is formed by the intersection of two cylindrical organs.

A cutting instrument **400** that creates easily and precisely a side-opening in a hollow tubular organ **414** is shown next in FIGS. **30** through **33**. The cutting instrument comprises a basic rigid rod **402** and a cutting cylinder **410** positioned slidingly over the rod. The cutting cylinder has a sharp lower edge **412**. A thin shaft **406** is affixed axially to the lower end **404** of the basic rod **400**. The shaft **406** ends up with a pointed barbed end **408**.

Cutting the sidewall of the hollow organ is shown in different phases in FIGS. **31** through **33**. First, the cutting instrument **400** is pushed down so the barbed end **408** of the shaft pierce the wall of the organ **414**, as shown in FIG. **31**. Then, the cutting cylinder **410** is slid down while the basic rod **402** is held in a stable position. The sharp edge **412** of the cylinder **410** cuts out the sidewall of the hollow organ **414**. After that, the cutting instrument is withdrawn, which lifts up the cutout portion **416** mounted on the pointed barbed end **408**, as shown in FIG. **33**.

Instruments that cut out an oval, ellipsoid, or other side-openings can be constructed in a similar manner. Cutting the ends of hollow tubular organs is a rather simple procedure, which can be accomplished by many cutting instruments already known in practice, and this is not described here.

It should be noted that openings in hollow organs can be also performed by other methods than cutting. Another method to create an opening is to pierce a hollow organ by a pointed rigid rod having external form and diameter corresponding to the form and diameter of the desired opening. This method is suitable for organs that consist predominantly of muscle tissues. The body of the pointed rigid rod pushes and displaces away the muscle fibers of the organ wall. This forms an opening in the organ without rupturing the wall and without cutting the muscle fibers, which preserves the functional capacity of the organ. In this way, connectors can be attached to the myocardial wall with a minimal damage to the heart. This is particularly important for implantation ventricular assist devices.

Connectors attached to hollow anatomical structure can be used for many other purposes. An example for this is shown and described next. Performing a stoma (a surgically constructed opening, especially one in the abdominal wall that permits the passage of waste after interrupting the natural passage) by a modified end connector is illustrated in FIGS. **34** through **36**. The modified connector **422** has an annular rigid body **424** and multiple holding members **426**. The connector **422** is further adapted with a radial wire mesh **428** attached to the lower edge of the annular body.

The surgical procedure is easy and simple to perform. The end **420** of a severed intestine **418** is drawn out through an incision **430** of the abdominal wall **434**. The modified connector **422** is attached to the intestinal end **420** by the deformed holding members **426**. The radial wire mesh **428** of the connector **422** is positioned between the skin **436** and the subcutaneous layers **438** of the abdominal wall **434**, and the skin incision is closed with several stitches **432**. A specimen bag **440** adapted with a correspondingly matching connector **442** can be coupled to the stoma.

The stoma constructed in this way has several important advantages. First, the end of the intestine is steadily kept above the skin and it can not withdraw back. Second, the radial wire mesh anchors the connector to the skin and eliminates the possibilities for formation of parastomal hernias. Third, a specimen bag can be securely attached to the intestinal end, which prevents embarrassing leaks. Fourth, the attached connector can be used to occlude the stoma by a cap for short periods. This is important for the individual when engaging in certain activities (such as sex or taking a bath), because it avoids the embarrassment from wearing a specimen bag or the risk a spontaneous intestinal leak from the stoma.

It should be noted, that instead of wire mesh, the connector could be also adapted with radial beams projecting into the subcutaneous tissues, which would be easier to remove when the constructed stoma is temporary, or it could be adapted with other means for anchoring it to the skin.

Various connectors can be constructed depending on the requirements of the anastomosis and on the tissue characteristics. When the first end of a graft is attached to a hollow organ, the surgeon has an access to the internal side of the anastomosis through the second end of the graft. In such cases, an indivisible union connector, formed by a consolidation of two annular rigid bodies of two connectors, can find beneficial application.

An indivisible union connector for end-to-end anastomosis illustrated in FIGS. **37A** through **40C.** Figures "**A**" show in perspective view the whole union connector and hollow organs, figures "**B**" shows the same elements crosscut in half in the same perspective views, and figures "**C**" are schematic illustrations of a portion of them as defined by the C* windows in figures "**B**". In FIG. **37** the union connector is shown above one of the two hollow organs, FIGS. **38** it is shown positioned over the hollow organ, in FIGS. **39** it is shown attached to the hollow organ, and in FIGS. **40** it is shown attached to end of both organs.

The indivisible union connector **502** consists of a first annular rigid portion **504** and a second annular rigid portion **506**, which actually constitutes the consolidated annular bodies of two end connectors. The union connector has first holding members **510** and second holding members **512**, which are actually the respective holding members of the consolidated connectors. The consolidated first annular portion **504** and second annular portion **506** form an inner fluidproof surface **508** that surrounds the cut-edges **518** and **520** of respective first hollow structure **514** and second hollow structure **516**.

Accomplishing an end-to-end anastomosis with the indivisible union connector is a similar to performing it with two end connectors. As shown here, the union connector **502** is positioned over the wall of a second hollow structure **516**. The second holding members **512** are then deformed to press the hollow structure **516** towards the outer second annular portion **506**. After that in the same way the first hollow structure **514** is affixed to the first annular portion **504** of the union connector by the first holding

members **510**. The fluidproof surface **508** of the union connector **502** surrounds the two approximated structures and does not permit a leak out of their abutted cut-edges **518** and **520**. In this way an end-to-end anastomosis is completed fast, easy, and securely.

The end-to-end anastomosis with the indivisible union connector is similar to the end-to-end anastomosis by two coupled end connectors. In the same way, the ends of the two hollow structures are precisely approximated with abutted cut-edges of their wall-openings. This positions the external, medium, and internal layers of the two walls in direct contact facing each other. Same layers of the two vessels meet and reconnect with each other. The hollow anatomical structures heal in a layer specific manner, which cannot be accomplished by other anastomosing devices.

When anastomosing blood vessels, foreign material in contact with the blood flow should be reduced to minimize risk of thrombus formation. Additional means for preventing blood vessels displacing axially out of the connectors might be needed for medium and large vessels, which conduct blood under high pressure.

A different embodiment of coupling end connectors adapted for application with medium and large blood vessels, and a method for their manufacture are illustrated in FIGS. **41A** through **42B**. Figure **41A** shows two end connectors in perspective view. The same connectors crosscut in half are shown in Figure **41B**. Figure **42A** demonstrates end-to-end anastomosis performed by the union of the two end connectors showing them crosscut in half in perspective view, and the same elements whole in the same view are shown in FIG. **42B**.

The two end connectors, first end connector **522** and second end connector **524,** are identical. They consist respectively of: first annular rigid body **526** and second annular rigid body **528**; first holding means **530** and second holding means **532**; first coupling plates **540** and second coupling plates **542**. They are respectively attached to first blood vessel **544** and second blood vessel **546**.

Performing an end-to-end anastomosis is accomplished in the already described manner -- attaching first connector **522** to first blood vessel **544** and second connector **524** to second blood vessel **546**, then coupling the attached connectors in a union. This creates a fluidproof surface that surrounds the abutted cut-edges **548** and **550** of first and second blood vessel respectively. Once again, the approximated ends of the two vessels are abutted with cut-edges of their openings, which allows a layer specific healing of their walls.

The holding members of this embodiment are designed to adapt to the specific requirements of large arterial blood vessels - less foreign material within the blood flow, and a necessity to prevent axial displacement of the adjoined vessel. Each holding member is made of a thin metal wire. It has an internal "**L**" shape portion **534** that presses the vessel to the annular rigid body. Through a small hole in the annular body, the wire exits out and turns into a short external portion **536** that runs axially to the middle and through a small hole enters back the annular body. The wire ends in a short radially pointed portion **538**. This radial portion penetrates the wall of the blood vessel and prevents axial displacement.

This configuration of the holding means allows for easy manufacture of the end connector. First, two small holes are drilled on the annular body. Then the ends of a "U" shaped wire are threaded from outside into the holes and the short external portion is welded. After that one wire end is formed in a "L" shape holding member and the other end is cut to create the short radial portion.

Another embodiment of an indivisible union connector for side-to-end anastomosis that can be particularly advantageous for vascular graft anastomoses, such as the aortic anastomosis of a coronary bypass graft, is shown in FIGS. **43A** through **46B.** Figure **43A** is a perspective top view of the connector. Figures **43B** and **44C** are perspective bottom views of the connector showing it whole and crosscut in half respectively.

The union connector **552** consists of a first annular rigid portion **554** and second annular rigid portion **556** that are seamlessly consolidated. It has an inner fluidproof surface **558**. First holding members **560** and second holding members **562** are affixed to the union connector. Both of them have "L" shape form. The first holding members **560** are aimed upward to accept the end of the first blood vessel **566**. The second holding members **562** are aimed downward so they can be inserted in the side-opening of the second blood vessel **568**. Each pair of adjacent first and second holding members are manufactured from a single wire and are interconnected on the outside by transverse portion **564** that is welded to the outside of the connector.

The union connector **552** attached to the end of first vessel **566** by deformed first holding members **560** is shown in top perspective view in FIG. **44A** and in bottom perspective view in FIG. **44B**. In the following two FIGS. **45A** and **45B**, the union connector **552** is illustrated in the same views attached to the first vessel **566** and positioned over the sidewall of the second vessel **568** so the second holding members **562** protrude along cut-edges **572** of the side-opening into the second vessel **568**. In the case of a coronary bypass graft anastomosis to the aorta, the second vessel (aorta) is much larger than the first vessel and the anastomosis is performed to a lightly arcuate surface that is illustrated as a flat surface for better clarity in the drawings. After the connector **552** is positioned over the side-opening of the second vessel **568**, the second holding members **562** are deformed to press the sidewall of the second vessel toward the second annular portion of the union connector.

A completed side-to-end anastomosis is shown in top perspective view in FIG. **46A** and crosscut in half in a bottom perspective view in FIG. **46B**. As seen, the two vessel walls are exactly approximated. Their cut-edges **570** and **572** abut exactly each other, which allows a layer specific healing of the same layers of both vessels. The inner fluidproof surface **558** surrounds the abutted cut edges **570** and **572** of the anastomosed walls and prevents leaks out of the anastomosis.

Another embodiment of an indivisible union connector for side-to-end vascular anastomoses is illustrate in schematic drawings in FIGS. **47A** through **49.** The union connector has a structure similar to the last described connector embodiment and will be briefly discussed. The indivisible union connector **576** has first holding members **576** for accepting the end of the first blood vessel **582** and second holding members **580** for accepting the side of the second blood vessel **584**.

The second holding members **580** are notably different. Their shape is predefined so when they are deformed, as shown with arrows in FIG. **47B**, they bend down and pierce the sidewall of the vessel **584** away from the anastomotic line. Further deformation bends them inward and they press the sidewall towards the rigid body of the outside connector. This is an important feature as it allows a closed anastomosis to be performed. The union connector **576** attached to the end of the first vessel **584** can be attached to the sidewall of the second vessel **586** before performing an opening in the second vessel. This can be beneficial in cases when clamping of the side vessel should be preferably avoided.

The side-to-end anastomosis performed by the indivisible union connector **576** is illustrated in FIG. **49**. As seen, cut-edges **586** and **588** of approximated first and second blood vessels **582** and **584** are again precisely abutted and surrounded by the inner fluidproof surface of the union connector.

Intestines have relatively thicker walls than other hollow body organs. Their walls are fragile and sutures can easily cut through. In cases of intestinal obstructions and infections, their walls swell and become extremely fragile. Anastomosing swollen intestines is an extremely risky procedure that can be complicated by serious and sometimes fatal consequences. In many of these cases, surgeons avoid anastomoses and interrupt the intestinal passage with an intestinal stoma.

Another embodiment of a union connector that could find beneficial application for end-to-end anastomosis of gastrointestinal organs is shown in FIGS. **50A** and **50B**. Two

intestinal organs **596** and **598** anastomosed by a union connector **590** are shown crosscut in perspective view in FIG. **50A**. A portion of them defined by window B* is shown magnified in a schematic view in FIG. **50B**.

The annular rigid body of the union connector **590** is similar to embodiments already described above. A different type of holding members **592** are used in this case to keep the intestinal walls adjoined to the internal surface of the connector **590**. Each one of the holding members **592** is pointed radially inward and has a barbed portion **594**. Intestinal walls are attached to the connector by pressing the walls outward over the radially pointed holding members **592**. The holding members penetrate the intestinal walls. Their barbed portions prevent the walls of moving way from the inner surface of the connector.

When compared to manual suturing, the intestinal walls are held by much higher number of holding members than sutures. Their holding force is evenly distributed on the anastomosed walls. This substantially reduces the risk of cutting through.

The process of intestinal healing is naturally quick and efficient. No additional forces are needed to support the intestinal anastomosis once the healing is completed. For that reason, materials that are absorbed by the body can be preferably used to manufacture intestinal connectors. Other different shapes of holding members, such as shapes used for Velcro attachments, can be used for the same purpose as well.

It should be also noted, that the connector of the present invention can be attached to other hollow structures that have different external surfaces. In a similar manner as described above, it can be attached to surfaces that are flat, spherical, conical, or irregular. The scull, the thorax, and the abdomen, which form respective body cavities, should be also construed as hollow structures to which the connector can be attached.

In should be also noted, that in a reciprocal manner the connector of the present invention can also be attached to the internal surfaces of hollow anatomical organs.

It should be also further noted that the connector of the present invention can also be used for many other surgical procedures. It can be used for anastomosing hollow anatomical organs by artificial or natural grafts, for bypass procedures, for transplant procedures, or for implantation of ventricular assist devices or total artificial hearts. It can be also used as a port entrance through which catheters, drains, or other conducting tubes are inserted securely into a body organ or cavity for diagnostic, therapeutic, or nutritional purposes.

The foregoing description of the principles of operation of the preferred embodiments of the connector for hollow anatomical organs made in conjunction with the various figures of the drawings are intended to be illustrative of the practice of the invention. Without departing from the principles of operation of the present invention, other embodiments and variations can be utilized, as described above.

Thus, the information disclosed in the description of the present invention is intended to be representative of the described principles. And as certain changes may be made without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative, but not in a limiting sense. It is also to be understood, that the following claims are intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.